COMPARISON OF SIGNAL RESPONSE BETWEEN EDM NOTCH AND CRACKS IN EDDY-CURRENT TESTING

Mark Kane and Ajay Koshti
September 29, 2008

CONTENTS

1. SCOPE

In the field of ET an eddy-current instrument is calibrated on a manufactured notch that is designed to simulate a defect in a part. The calibrated instrument is then used to scan parts with the assumption that any response that is over half the amplitude of the notch signal is taken to be defective.

The purpose of this study is to attempt a direct comparison of the signal response observed from an EDM notch to a crack of the same size. To make this comparison test equipment will be set up and calibrated as per normal inspection procedures. Once this has been achieved both notches and as many different sizes of crack specimens will be scanned and the data recorded. This data will then be analyzed to provide a comparison of the response. The results should also provide information that shows it is acceptable to use the half-amplitude method for determining if a part is defective.

The tests will be performed on two different materials commonly inspected, titanium and aluminum. This will allow a comparison of the results between materials.

2. TEST OBJECTIVES

Objective	
EDM NOTCH AND DEFECT SIGNAL RESPONSE	
2.1	Evaluate signal response of titanium EDM notches and fatigue crack specimines of known defect size. Use the aquired data to develop a transfer function to correlate EDM response to defect response.
2.2	Perform tests with aluminum so differences between aluminum and titanium can be made.

Table 2-1 Test Objectives

3. MATERIALS

3.1 EQUIPMENT

ITEM
Kapton Adhesive
Plastic straight-edge
Pencil
Scale
MIZ-17 ET; ethernet capability
NDT AZ-BN/200K Voltage Regulator
NDT MP-40/1M Absolute Probe
EDM NEC-645-6AL Titanium Standard
Computer
NDT MP-30 50-500KHZ Absolute Probe
NDT AZ-BN 1M Voltage Regulator

Table 3-1: Equipment

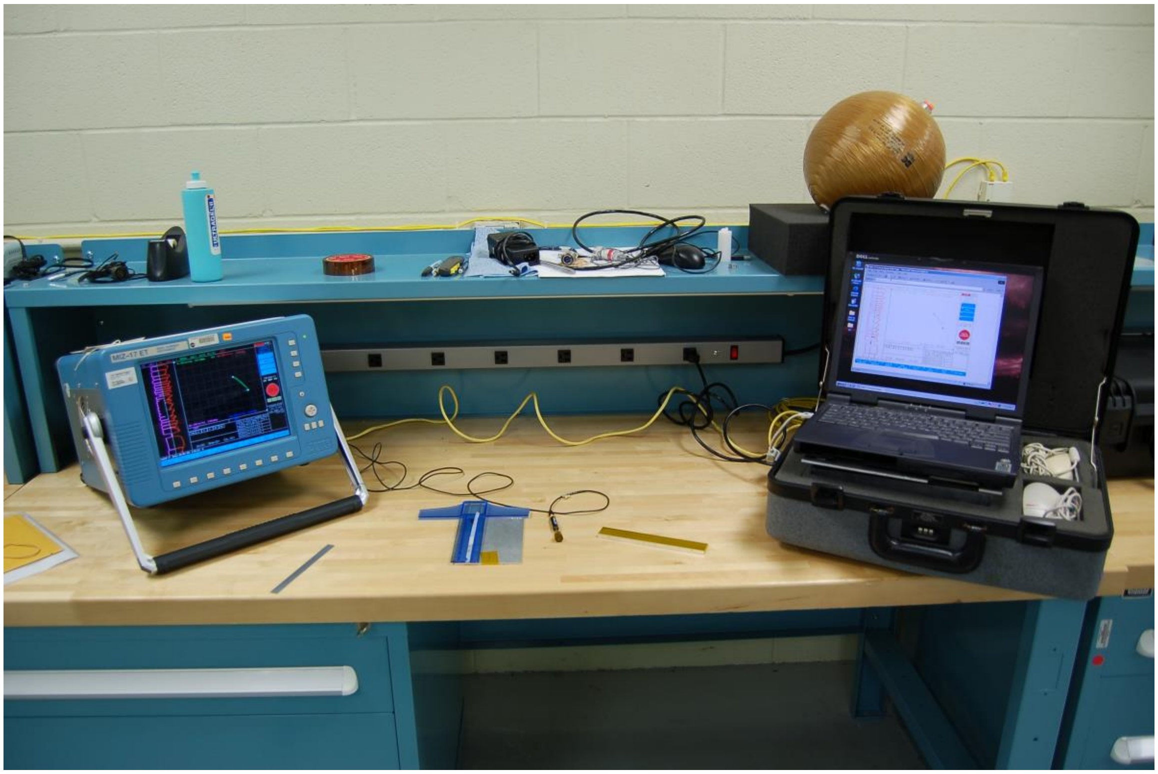
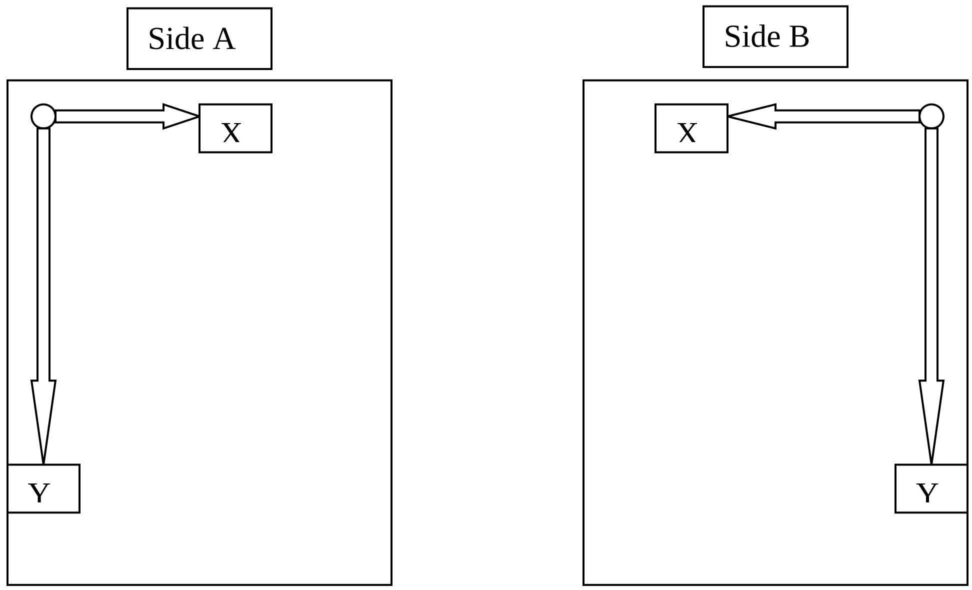


Figure 3-1: Test Set-up

3.2 TEST SAMPLES

Following MIL-HDBK-1823 numerous flawed sites will be inspected to give reasonable results for the POD analysis. The sample data along with test results can be found in **Appendix A** notch data can be found in **Appendix B.**



1. The front of the sample is considered to be the side with the serial number stamp.
2. The corner hole is always considered to be the origin. The x direction travels along the width and the y direction along the length.

3.3 TEST PROCEDURE

3.3.1 Ensure that equipment is on and check all plug-ins and other connections.
3.3.2 Using a pencil and given defect data mark the location of the defect on the specimen and then cover in a protective layer of tape.
3.3.3 Calibrate Equipment on notch at required frequency to achieve proper depth of penetration.
3.3.4 Keeping the settings exactly the same scan sample defects and other notches of varying size.
3.3.5 Utilizing the electronic measuring of the MIZ-17 find both signal amplitude and phase angle.
3.3.6 Capture the MIZ-17 screen on the connected computer and store data.

NOTE: For accuracy in results the notches used are semi-circular to best approximate a typical crack found in parts.

4. RESULTS

4.1 TITANIUM

The test configuration used for the titanium samples can be seen in **Table** Using this configuration the depth of penetration is approximately .015 inches.

Equipment	MIZ-17 ET
Probe	NDT MP-40/1M
Voltage Regulator	NDT AZ-BN 1M
Standard	EDM NEC-645-6AL
Test Setup	
Frequency	1 Mhz
Gain	46 dB
Probe Drive	13.0V
xy	0.1
xy	0.28
Voltage multiplier	1.62
Rotation	308 deg
Filter	BP 0-50Hz

Table 4-1: Titanium Test Configuration

Figure 4-1 and Figure 4-2 are scatter-plots of the data collected from the titanium test samples and EDM notches. The data shows that the signal amplitude increases linearly with crack size; the signal response however will reach a saturation point once the defect is large enough in which case the signal would cease to follow this linear trend.

A trend-line was inserted into the graph; the R-squared value is close to one and shows that the data fits a linear trend. The equation of the trend line is given and used later in comparison of the notch and crack predicted values. **Figure 4-3** is a plot of the trend lines from both the notches and cracks using the equations for the trend lines seen in **Figures 4-31and 4-2**.

The purpose of these tests is to compare the response of an EDM notch to that of a crack in a part. For this comparison the predicted crack signal response was calculated as a percentage of the predicted notch signal response. The results can be seen in **Figure 4-4.** As can be seen in this figure the difference between the two follows a logarithmic curve. More importantly it can be seen that at a crack size of approximately .050 inches, the same size as the notch that was calibrated on, gives a signal response is just over half of the calibrated response signal. This shows experimentally that it is reasonable to calibrate on a notch and then consider any response that is half of the amplitude or more to be defective.

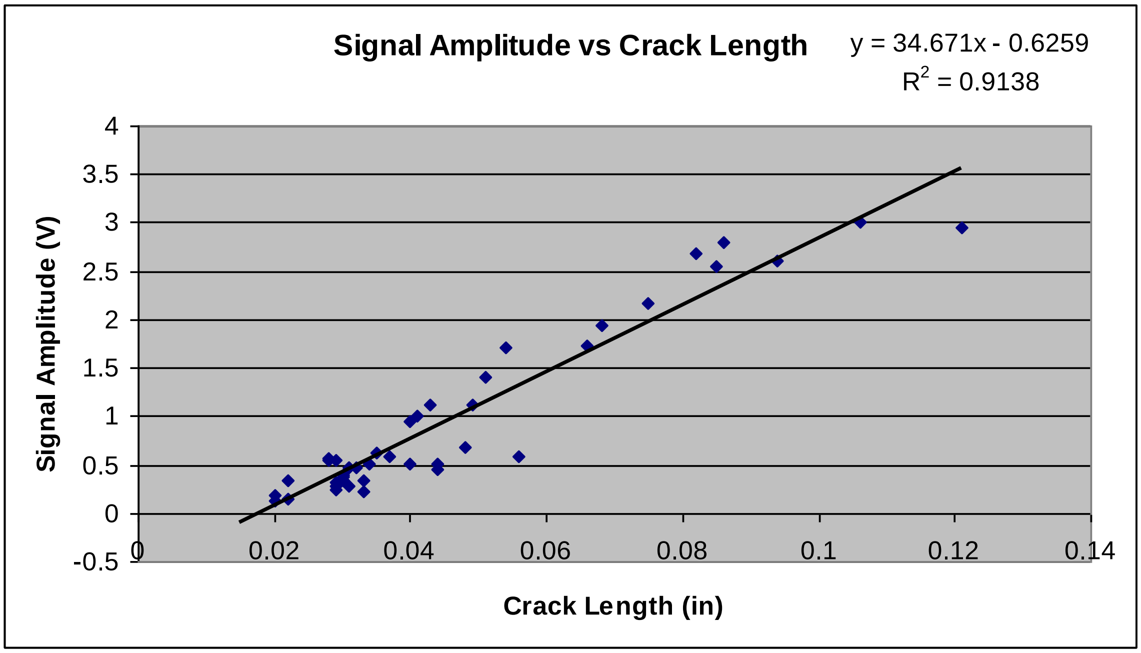


Figure 4-1: Titanium Crack Amplitude Data with Trend Line

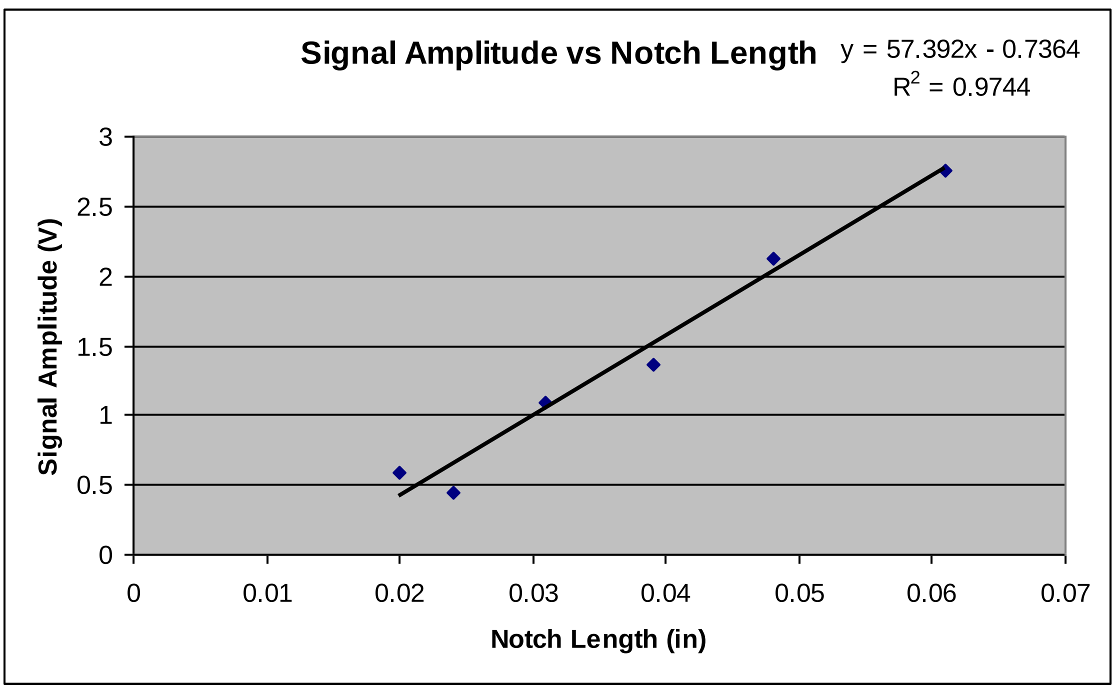


Figure 4-2: Titanium Notch Amplitude with Trend Line

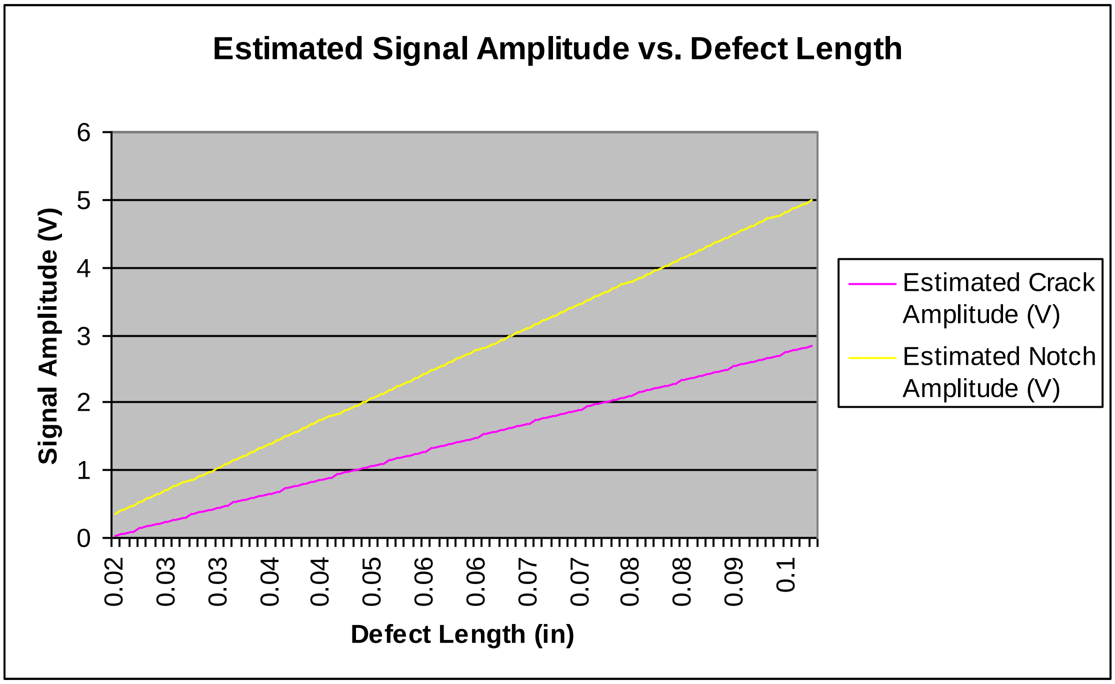


Figure 4-3: Titanium Predicted Values

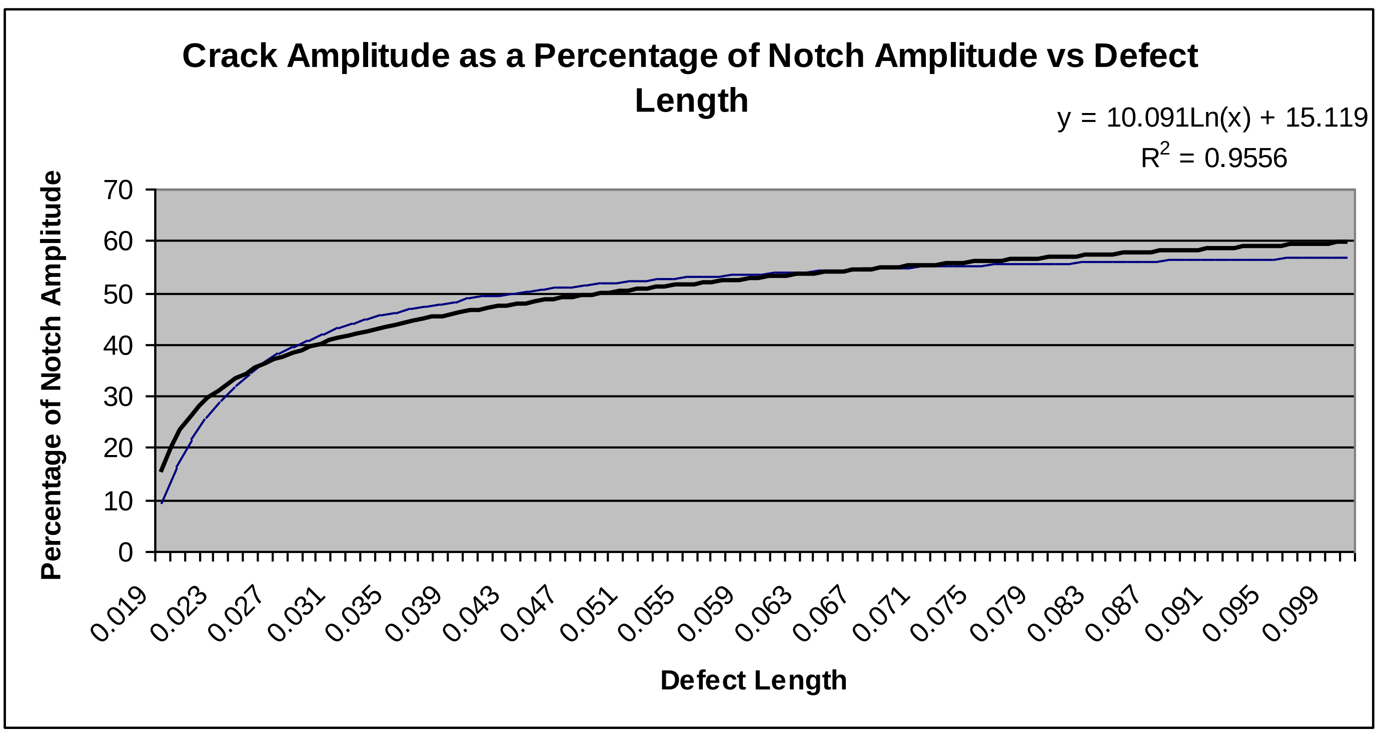


Figure 4-4: Titanium Crack Amplitude as a Percentage of Notch Amplitude

4.2 ALUMINUM

Table 4-1 shows the set-up used for the testing with the aluminum samples. At these settings the depth of penetration is approximately .012 inches.

Equipment	MIZ-17 ET
Probe	NDT MP-30 50-500KHZ
Voltage Regulator	NDT AZ-BN/200K
Standard	NEC-6365-2024T3
Test Setup	
Frequency	80 KHz
Gain	40 dB
Probe Drive	11.0 V
xy	0.1
xy	0.23
Voltage multiplier	2
Rotation	51 deg
Filter	

Table 4-1: Aluminum Test Configuration

Figure 4-5 and Figure 4-6 are scatter-plots of the data collected from the aluminum samples and EDM notches. The data is similar to the titanium data in that it shows that the signal amplitude increases linearly with crack size.
As with the titanium sample the R-squared value of the trend line shows that the aluminum data also fits a linear trend well. **Figure 4-7** is a plot of the trend lines from both the notches and cracks using the equations seen in **Figures 4-1** and **4-2**.

Figure 4-5 shows the predicted crack amplitude as a percentage of predicted notch amplitude.

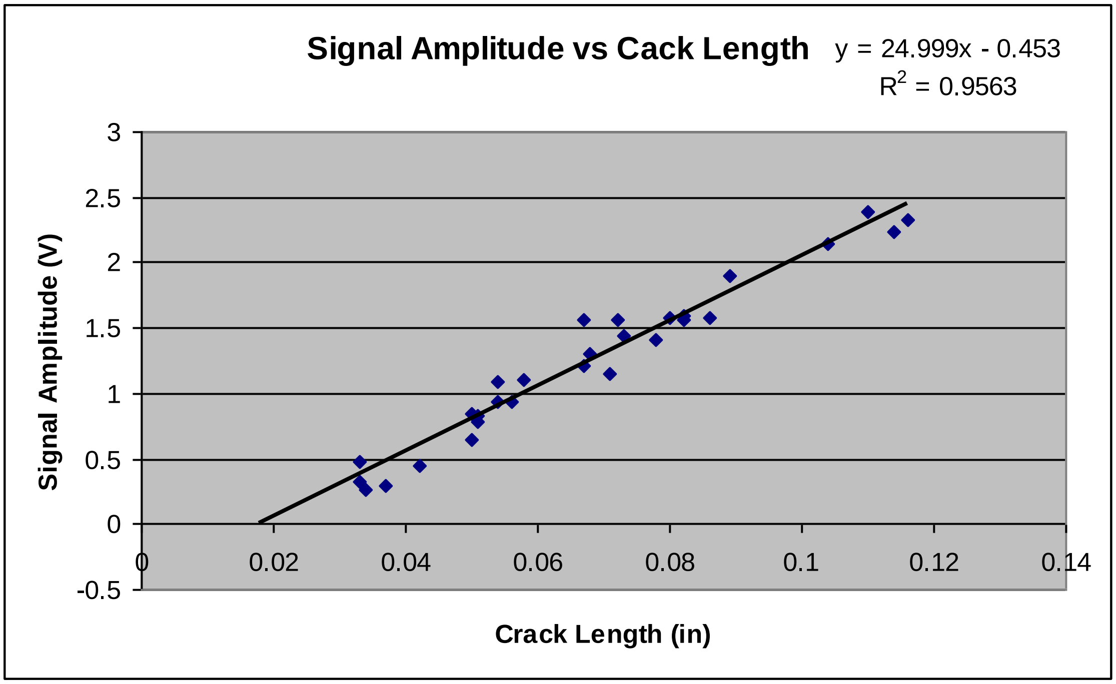


Figure 4-5: Aluminum Amplitude Data with Trend Line

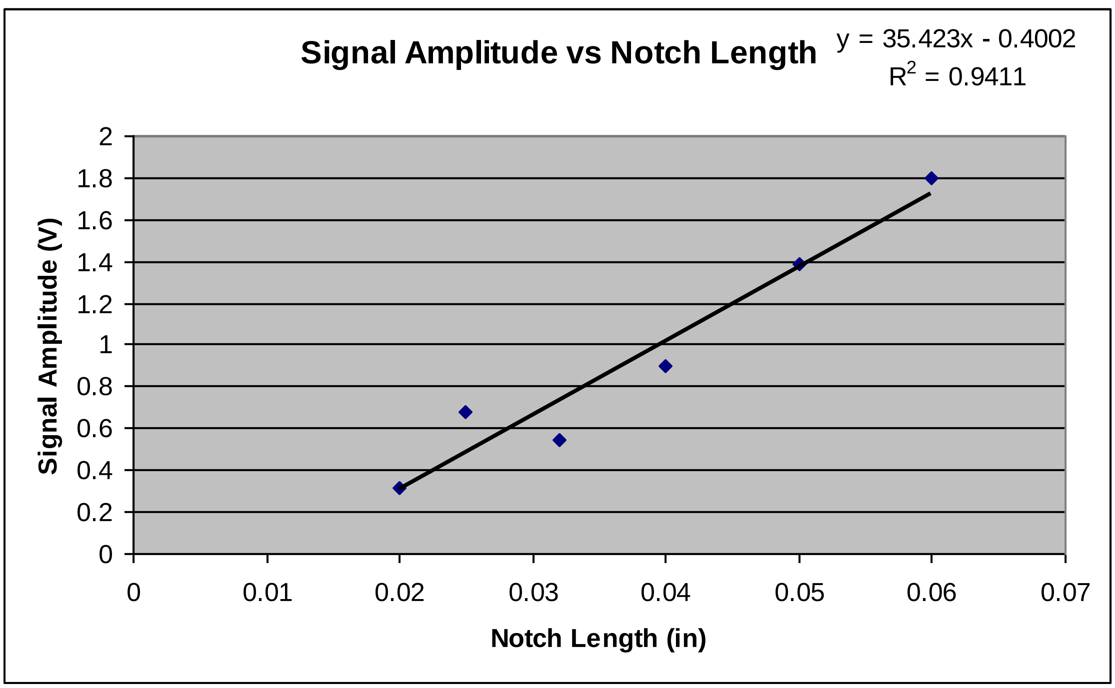


Figure 4-6: Aluminum Notch Amplitude with Trend Line

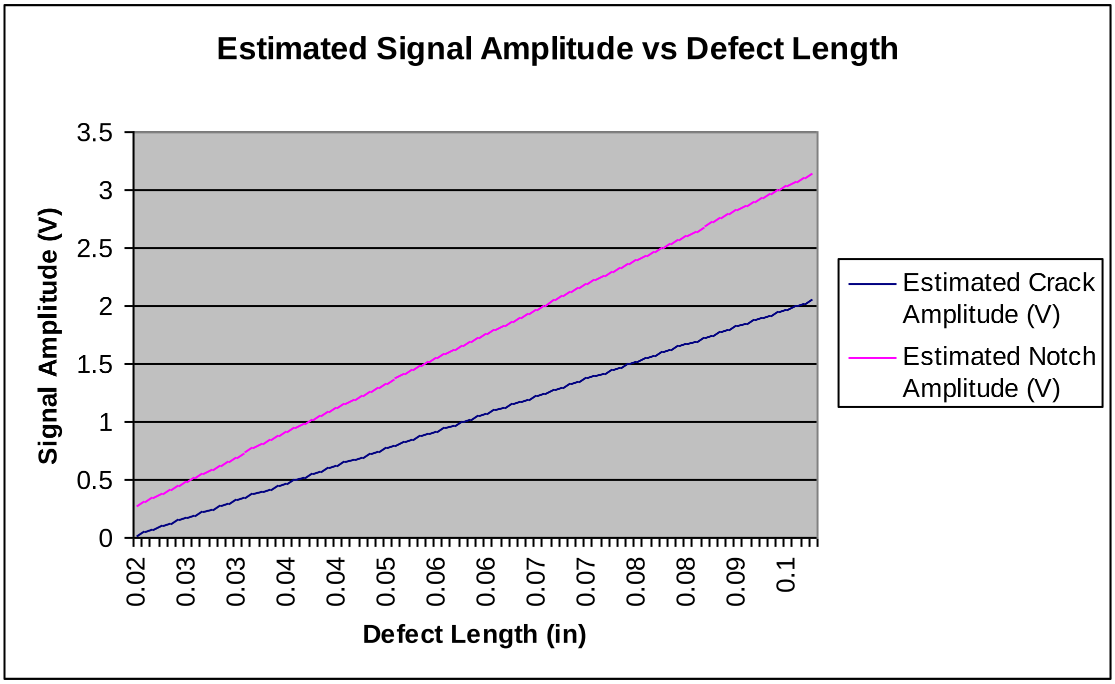


Figure 4-7: Aluminum Predicted Values

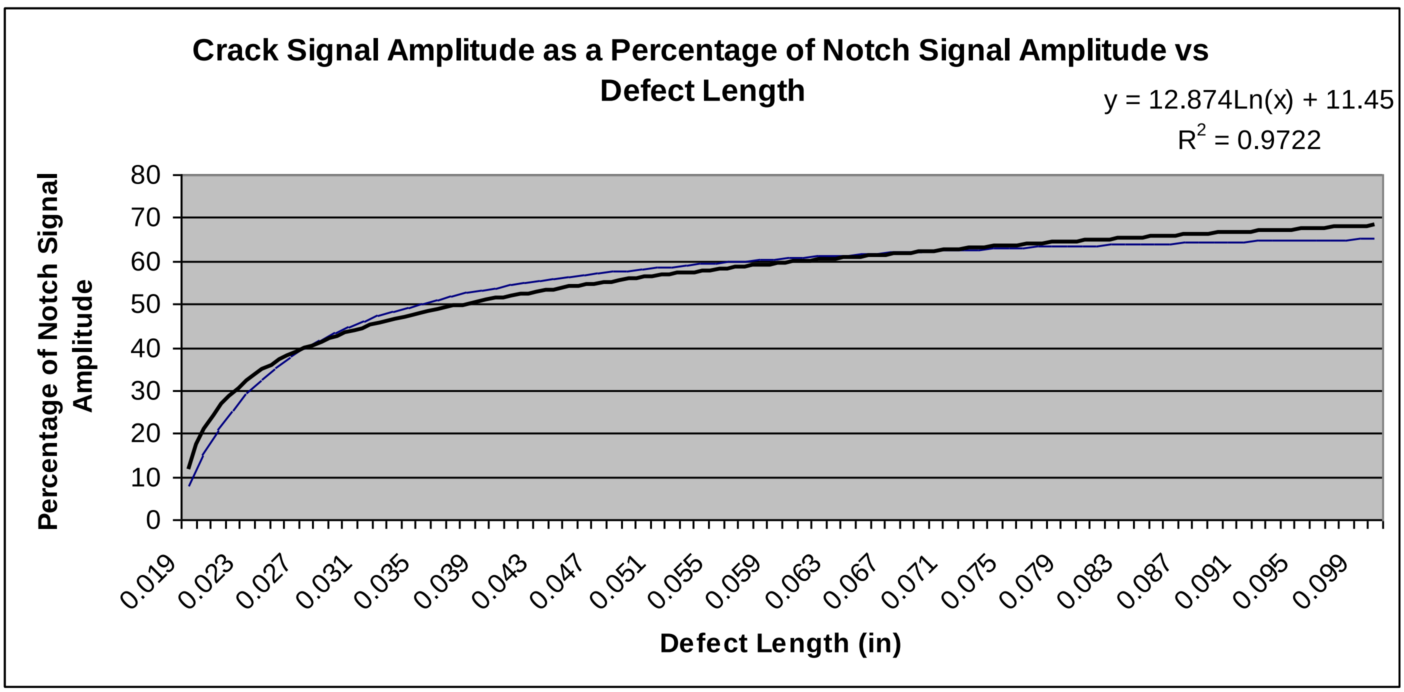


Figure 4-8: Aluminum Crack Amplitude as a Percentage of Notch Amplitude

5. CONCLUSION

As expected the data shows that and EDM notch will give a higher signal amplitude than a crack of the same size. The notch is manufactured giving it clean edges that produce a clear response as appose to uneven edges that would be seen in a typical defect seen in a specimen.

The data shows that the signal response increases linearly with increase in defect size. This is validated by the defects seen in the specimens scanned and in the EDM notch standards. These results are further validated by the second set of tests with the aluminum samples.

Phase angle was also compared to defect size; there seemed to be a general trend of increased phase angle with defect size the data was scattered enough to require more testing to achieve a correlation.

While aluminum and titanium showed linearity in signal response with respect to defect length, they exhibited different magnitudes. For these tests the aluminum showed lower signal response in comparison to the titanium samples; aluminum did exhibit crack signal response that is much closer to the response of a notch of the same size. As crack size increased the crack response more quickly approached notch response in aluminum than in titanium.

The results seen in this document are believed to be accurate and of good quality by using the same equipment and following the same procedure as much user error was eliminated as possible. The test configuration was chosen to provide similar depth of penetration in both of the materials so that it would be reasonable to compare the signal responses.

APPENDIX A: CRACK DATA

Titanium Crack Data									
S/N	Crack	Side	X-location (in)	Y-location (in)	Length (in)	Depth (in)	P/F	Signal Amplitude (V)	Phase Angle (deg)
1A24	1	B	1.25	5.25	0.021	0.0105	0		
4G53	1	B	2.8	5.15	0.056	0.028	1	0.58	6
4X82	1	A	2.19	5.4	0.025	0.0125	0		
5S59	1	B	1.2	0.6	0.033	0.0165	1	0.23	13
5S59	2	B	2.63	2.1	0.037	0.0185	1	0.58	14
8B06	1	B	2.04	0.04	0.04	0.02	1	0.51	12
8B06	2	B	3.2	1.98	0.068	0.034	1	1.95	10
8B06	3	B	3.2	3.7	0.033	0.0165	1	0.34	13
8B06	4	B	1.95	5.25	0.031	0.0155	1	0.28	14
9H97	1	B	0.75	4	0.019	0.0095	0		
9H97	2	B	2.7	5.5	0.022	0.011	1	0.33	
33W0	1	A	2.8	3.8	0.085	0.0425	1	2.56	11
33W0	2	A	2.2	5.25	0.041	0.0205	1	1.01	8
35T6	1	A	0.66	0.78	0.048	0.024	1	0.69	6
35T6	2	A	1.75	2	0.044	0.022	1	0.51	5
35T6	3	A	3.12	2.95	0.075	0.0375	1	2.17	12
35T6	4	A	0.72	5.1	0.044	0.022	1	0.46	8
41J9	1	A	2.99	0.54	0.032	0.016	1	0.48	8
41J9	2	A	2.97	2	0.029	0.0145	1	0.24	7
41J9	3	A	2.97	3.48	0.031	0.0155	1	0.47	3
41J9	4	A	2.99	4.84	0.035	0.0175	1	0.62	6
051D	1	B	3.28	5.32	0.054	0.027	1	1.71	10
57G3	1	B	2.35	5.03	0.049	0.0245	1	1.12	11
A849	1	B	3.03	3.75	0.051	0.0255	1	1.41	10
A849	2	B	1.33	5.25	0.094	0.047	1	2.61	15
B913	1	B	2.78	1.03	0.03	0.015	1	0.39	12
B913	2	B	1.29	2.27	0.015	0.0075	0		
B913	3	B	1.88	3.73	0.02	0.01	1	0.18	6
B913	4	B	2.45	5.06	0.02	0.01	1	0.13	
C571	1	B	2.75	0.7	0.03	0.015	1	0.34	10
H179	1	B	2.57	0.68	0.029	0.0145	1	0.29	13
J687	1	B	2.83	0.69	0.028	0.014	1	0.54	2
M979	1	A	2.72	0.35	0.031	0.0155	1	0.47	9
M979	2	A	1.7	1.9	0.029	0.0145	1	0.32	9
0T92	1	B	1.58	3.87	0.028	0.014	1	0.57	11
0T92	2	B	3.01	5.06	0.029	0.0145	1	0.55	5
P632	1	A	1.8	4.1	0.082	0.041	1	2.68	13
P632	2	A	2.86	5.36	0.03	0.015	1	0.34	11
P748	1	A	2.75	0.75	0.121	0.0605	1	2.95	21
P748	2	A	1.5	2	0.066	0.033	1	1.74	7
P748	3	A	2.42	3.65	0.04	0.02	1	0.95	5
P748	4	A	0.7	5.3	0.106	0.053	1	3	17
T869	1	A	0.67	2.45	0.03	0.015	1	0.37	10
T869	2	A	2.78	0.7	0.02	0.01	0		
U652	1	B	3	0.42	0.022	0.011	1	0.14	
U652	2	B	0.96	2.15	0.019	0.0095	0		
V970	1	B	0.75	5.3	0.043	0.0215	1	1.12	5
Z208	1	B	2.6	3.48	0.086	0.043	1	2.8	15
Z208	2	B	1.3	520	0.034	0.017	1	0.52	9

Table A-1: Titanium Crack Data

APPENDIX A: CRACK DATA

Aluminum Crack Data									
S/N	Crack	Side	X-location (in)	Y-location (in)	Length (in)	Depth (in)	P/F	Signal Amplitude (V)	Phase Angle (deg)
2H10	1	A	2	5.35	0.051	0.0255	1	0.83	38
2U58	1	B	3.05	0.65	0.078	0.039	1	1.41	36
2U58	2	B	2.4	2.15	0.11	0.055	1	2.39	31
2U58	3	B	1.89	3.55	0.089	0.0445	1	1.9	34
2U58	4	B	1.38	4.9	0.067	0.0335	1	1.21	28
4A47	2	B	1.5	2.2	0.034	0.017	1	0.27	21
6I86	1	A	2.42	0.65	0.054	0.027	1	0.93	25
40U2	1	A	1.5	0.82	0.08	0.04	1	1.58	39
55Z2	1	B	0.85	0.6	0.116	0.058	1	2.32	22
55Z2	2	B	2.13	2.1	0.021	0.0105	0		
58K9	1	B	2.05	0.8	0.067	0.0335	1	1.56	34
58K9	2	B	2.94	2.5	0.054	0.027	1	1.09	27
58K9	3	B	0.9	4.44	0.056	0.028	1	0.94	26
58M3	1	A	2.8	3.95	0.018	0.009	0		
58M3	2	A	0.6	5.3	0.018	0.009	0		
69I2	1	A	2.45	4.3	0.068	0.034	1	1.3	29
69I2	2	A	0.88	5.75	0.033	0.0165	0		
87U7	1	A	2.18	3.78	0.027	0.0135	0		
87U7	2	A	1.46	5	0.033	0.0165	1	0.48	16
89H3	1	B	2.12	1	0.033	0.0165	1	0.33	10
89H3	2	B	0.85	2.5	0.05	0.025	1	0.64	29
89H3	3	B	2.12	3.54	0.072	0.036	1	1.57	32
89H3	4	B	0.85	5.2	0.082	0.041	1	1.6	36
98H0	1	B	3.02	5.6	0.05	0.025	1	0.84	25
374D	1	A	1.3	0.85	0.037	0.0185	1	0.29	26
481S	1	B	2.5	0.95	0.071	0.0355	1	1.15	27
481S	2	B	1.23	2.45	0.086	0.043	1	1.58	36
481S	3	B	1.23	3.9	0.024	0.012	0		
481S	4	B	2.6	5.1	0.104	0.052	1	2.14	34
883A	1	B	1.3	0.58	0.073	0.0365	1	1.44	32
883A	2	B	2.62	1.2	0.114	0.057	1	2.23	35
883A	3	B	3.2	2.5	0.058	0.029	1	1.1	26
883A	4	B	3.2	3.8	0.082	0.041	1	1.56	36
883A	5	B	0.86	4.84	0.042	0.021	1	0.44	10
925F	1	B	1.62	0.56	0.051	0.0255	1	0.79	23

Table A-2: Aluminum Crack Data

APPENDIX B: NOTCH DATA

EDM-NEC 6465-6AL: Titanium semi-circular notches				
Notch	**Length (in)**	**Depth(in)**	**Signal Amplitude (V)**	**Phase Angle (deg)**
A1	0.02	0.01	0.59	
A2	0.024	0.013	0.45	11
A3	0.031	0.014	1.09	5
A4	0.039	0.018	1.36	6
A5	0.048	0.025	2.13	7
A6	0.061	0.029	2.76	8

Table B-1: Titanium Notch Data

NEC-6365-2024T3 - Aluminum semi-circular notches				
Notch	**Length (in)**	**Depth(in)**	**Signal Amplitude (V)**	**Phase Angle (deg)**
A1	0.02	0.01	0.32	14
A2	0.025	0.013	0.68	16
A3	0.032	0.016	0.55	15
A4	0.04	0.019	0.9	24
A5	0.05	0.023	1.39	22
A6	0.06	0.028	1.8	23

Table B-2: Aluminum Notch Data